PART IV: RISK ASSESSMENT

HAZARD IDENTIFICATION PROCESS

Hazards were identified and evaluated for inclusion in this plan based on historical review of past events, synthesis of existing reports, data and hazard mapping analysis, and finally input from local level emergency management personnel and other community officials. Consideration for inclusion was based on the likelihood of a hazard's occurrence, location of the occurrence and the potential impact of the event in terms of it effect on human life and property (See Table IV-1).

Surveys were sent to the chief elected official for all jurisdictions in the Bear River District. Among other questions, the survey instrument requested local input on hazard identification, completed and needing hazard mitigation projects, participation in the National Flood Insurance Program and the existence of hazard maps and ordinance for their locality (See Appendix A).

Table IV-1: Hazard Identification & Justification for Inclusion

Hazard	How Identified	Why Identified
Earthquake	Local Official Surveys Review of Local Emergency Operations Plans Input from City and County Emergency Operations Managers United States Geological Survey Utah Geological Survey	Bear River District has experienced both the largest (1934 Hansel Valley 6.54 Magnitude) and the most damaging (1962 Richmond 5.7 Magnitude) in the state's modern history (cost $1 Million in 1962 dollars). Numerous faults throughout region Located in the Intermountain Fault Zone.
Flood	Local Official Surveys Review of Local Emergency Operations Plans JUB Study of Cache Canals Input from City and County Emergency Operations Managers Utah Geological Survey Flood Insurance Study Army Corps of Engineers	Several previous incidents have caused severe damage and loss of life Many of the rivers and streams are located near neighborhoods Many neighborhoods are located on floodplains, alluvial fans Exposure to risks are increasing
Landslide	Local Official Surveys Review of Local Emergency Operations Plans Input from City and County Emergency Operations Managers Utah Geological Survey	Historically problematic Can be deadly
Wildfire	Local Official Surveys Input from City and County Emergency Operations Managers Utah Forestry, Fire and State Lands	Historically Problematic Associated with flooding, earthquake
Dam Failure	Local Official Surveys Review of Local Emergency Operations Plans Input from City and County Emergency Operations Managers Utah Division of Water Rights, Dam Safety Section	Can cause serious damage to life and property and have subsequent effects such as flooding, fire, debris flow, etc.

Table IV-1: Hazard Identification & Justification for Inclusion		
Hazard	**How Identified**	**Why Identified**
Drought, Infestation & Severe Weather	Local Official Surveys Review of Local Emergency Operations Plans Input from City and County Emergency Operations Managers Utah State University Agricultural Extension	Potential significant effect one of the largest sectors of the region's economy. Previous experiences

HAZARD DEFINITIONS

The following is a description of each of the hazards evaluated in the Bear River District Pre-disaster Mitigation Plan. These definitions, with minor modifications, were developed by DESHS and used by permission in this plan.

Flooding

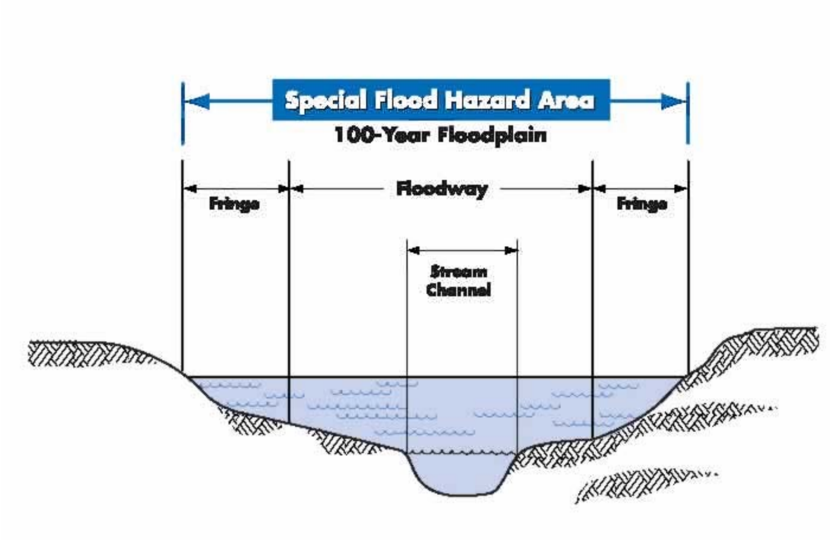
Flooding is a temporary overflow of water onto lands not normally inundated by water producing measurable property damage or forcing evacuation of people and vital resources. Floods frequently cause loss of life; property damage and destruction; damage and disruption of communications, transportation, electric service, and community services; crop and livestock damage and loss, and interruption of business. Floods also increase the likelihood of hazard such as transportation accidents, contamination of water supplies, and health risk increase after a flooding event.

Several factors determine the severity of floods including rainfall intensity, duration and rapid snowmelt. A large amount of rainfall over a short time span can result in flash flood conditions. Small amounts of rain can also result in flooding at locations where the soil has been previously saturated or if rain concentrates in an area having, impermeable surfaces such as large parking lots, paved roadways, or post burned areas with hydrophobic soils. Topography and ground cover are also contributing factors for floods. Water runoff is greater in areas with steep slopes and little or no vegetative ground cover.

Frequency of inundation depends on the climate, soil, and channel slope. In regions where substantial precipitation occurs during a particular season or in regions where annual flooding is due to spring melting of winter snow pack, areas at risk may be inundated nearly every year.

Conditions which my exacerbate floods include: steeply sloped watersheds, constrictions, obstructions, debris contamination, soil saturation and velocity.

Explanation of Common Flood Terms



FIRM: Flood Insurance Rate Map

100-year flood: Applies to an area that has a 1 percent chance, on average, of flooding in any given year. However, a 100-year flood could occur two years in a row, or once every 10 years. The 100 year-flood is also referred to as the base flood.

Base Flood: Is the standard that has been adopted for the NFIP. It is a national standard that represents a compromise between minor floods and the greatest flood likely to occur in a given area and provides a useful benchmark.

Base Flood Elevation (BFE): As shown on the FIRM, is the elevation of the water surface resulting from a flood that has a 1% chance of occurring in any given year. The BFE is the height of the base flood, usually in feet, in relation to the National Geodetic Vertical Datum (NGVD) or 1929, the North American Vertical Datum (NAVD) of 1988, or other datum referenced in the FIS report.

Special Flood Hazard Area (SFHA): Is the shaded area on a FIRM that identifies an area that has a 1% chance of being flooded in any given year (100-year floodplain).

Floodway: Is the stream channel and that portion of the adjacent floodplain that must remain open to permit passage of the base flood without raising that water surface elevation by more than one foot.

Earthquakes

An earthquake is the abrupt shaking of the earth caused by the sudden breaking of rocks when they can no longer withstand the stresses, which build up deep beneath the earth's surface. The rocks tend to rupture along weak zones referred to as faults. When rocks break they produce seismic waves that are transmitted through the rock outward producing ground shaking. Earthquakes are unique multi-hazard events, with the potential to cause huge amounts of damage and loss. Secondary effects of a sudden release of seismic energy (earthquake) include: ground shaking, surface fault rupture, liquefaction, tectonic subsidence, slope failure, and various types of flooding.

The Intermountain Seismic Belt

The Intermountain Seismic Belt (ISB), which the Bear River Region is part of, is a zone of pronounced earthquake activity up to 120 miles wide extending in a north south direction 800 miles from Montana to northern Arizona. The Utah portion of the ISB trends from the Easter Box Elder and Cache County area south through the center of the state, along the Wasatch Front, and the southwest through Richfield and Cedar City concluding in St. George. "The zone generally coincides with the boundary between the Basin and Range physiographic province to the west and the Middle Rocky Mountains and Colorado Plateau physiographic provinces to the east" (Eldredge 6).

Secondary Earthquake Threats

The major secondary effects of earthquakes include: ground shaking, surface fault rupture, liquefaction, tectonic subsidence, avalanches, rock fall, slope failure, and various types of flooding. Other sections discuss landslides, and flooding therefore they will not be discussed under secondary effects of earthquakes yet importance needs to be given to the fact that earthquakes can increase the likelihood of flooding and landslides.

Ground Shaking

Ground shaking causes the most impact during an earthquake because it affects large areas and is the origin of many secondary effects associated with earthquakes. Ground shaking, which generally lasts 10 to 30 seconds in large earthquakes, is caused by the passage of seismic waves generated by earthquakes. Earthquake waves vary in both frequency and amplitude. High frequency low amplitude waves cause more damage to short stiff structures, were as low frequency high amplitude waves have a greater effect on tall (high-rise) structures. Ground shaking is measured using Peak Ground Acceleration (PGA). The PGA measures the rate in change of motion relative to the established rate of acceleration do to gravity.

Local geologic conditions such as depth of sediment and sediment make up, affect earthquake waves. Deep valley sediments increase the frequency of seismic waves relative to bedrock. In general, ground shaking increases with increased thickness of sediments" (Eldredge 8).

Surface Fault Rupture

During a large earthquake fault movement may propagate along a fault plain to the surface, resulting in surface rupture along the fault plain. Most faults in the Bear River District are normal (mountain building) faults with regards to movement, meaning the footwall of the fault moves upward and the hanging wall moves in a down direction. Thus faulting is on a vertical plain, which results in the formation of large fault scarps. In historic time surface fault rupture has only occurred once in Utah; the 1934 Hansel Valley earthquake in Box Elder County with a magnitude 6.6 produced 1.6 feet of vertical offset.

Surface fault rupture presents several hazards, anything built on top of the fault or crossing the fault has a high potential of being destroyed in the event of displacement. Foundations will be cracked, buildings torn apart, damage to roads, utility lines, pipelines, or any other utility line crossing the fault. It is almost impossible to design anything within reasonable cost parameters to with stand an estimated displacement of 16 to 20 feet.

Surface fault rupture doesn't occur on a single distinct plain; instead it occurs over a zone often several hundred feet wide known as the zone of deformation. This zone of deformation occurs mainly on the down thrown side of the main fault trace. Tectonic subsidence, caused by antithetic faults moving in the opposite direction of the main fault, slide down hill on the main fault scarp creating grabens (down dropped blocks) within the zone of deformation.

Hintze described an “enigma” of Utah in that seismicity does not always coincide with surface fault scarps or faults (Geologic History of Utah, 1988). The epicenter of the earthquake may be miles away from the surface faulting.

Liquefaction

Soil liquefaction occurs when water-saturated cohesionless sandy soils are subject to ground shaking. When liquefaction occurs soils behave more like a viscous liquid (quicksand) and lose their bearing capacity and shear strength. Two conditions must be met in order for soils to liquefy: (1) the soils must be susceptible to liquefaction (sandy, loose, water-saturated, soils typically between 0 and 30 feet below the ground surface) (2) ground shaking must be strong enough to cause susceptible soils to liquefy (lips). The loss of shear strength and bearing capacity due to liquefaction causes buildings to settle or tip and light buoyant structures such as buried storage tanks and empty swimming pools to float upward. Liquefaction can occur during earthquakes of magnitude 5.0 or greater.

Lateral Spread

Soils, once liquefied, can flow on slopes with angles of .5 to 5 percent this movement of liquefied soils is known as lateral spread. "The surficial soil layers break up and sections move independently, and are displaced laterally over a liquefied layer" (Eldredge 10). Liquefaction can cause damage in several way, with lateral spreading being one of the most common. Displacement of three (3) or more feet may occur and be accompanied by ground cracking and vertical displacement. Lateral spreading causes roads, buildings, buried utilities, and any other buried or surface structure to be pulled apart.

Various Flooding Issues Related to Earthquakes

Earthquakes could cause flooding due to the tilting of the valley floor, dam failure and seiches in lakes and reservoirs. Flooding can also result from the disruption of rivers and streams. Water tanks, pipelines, and aqueducts may be ruptured, or canals and streams altered by ground shaking, surface faulting, ground tilting, and landsliding.

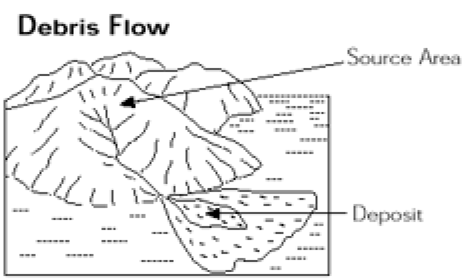
Seiches

Standing bodies of water are susceptible to earthquake ground motion. Water in lakes and reservoirs may be set in motion and slosh from one end to the other, much like in a bathtub. This motion is called a seiche (pronounced "saysh"). A seiche may lead to dam failure or damage along shorelines.

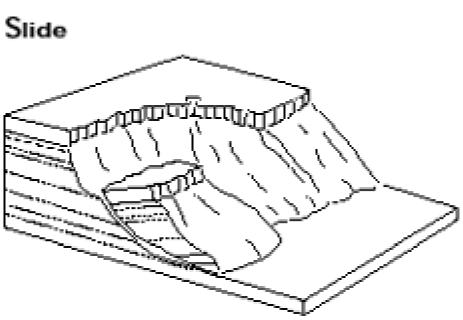
Landslides

Landslides are a "down slope movement of a mass of rock, earth, or debris". Landslides, often referred to as mass wasting or slope failures, are one of the most common natural disasters. (Cruden 36). Slope failures can vary considerably in shape, rate of movement, extent, and effect on surrounding areas. Slope failures are classified by there type of movement, and type of material. The types of movement are classified as falls, slides, topples, and flows. "The types of material include rock, debris (coarse grained soil) and earth (fine grained soil)" (Eldredge 17). "Types of slope failures then are identified as rock falls, rock slides, debris flows, debris slides, and so on" (Eldredge 17). Slope failures occur because of either an increases in the driving forces (weight of slope and slope gradient) or a decrease in the resisting forces (friction, or the strength of the material making up a slope). "Geology (rock type and structure), topography (slope gradient), water content, vegetative cover, and slope aspect are important factors of slope stability" (Eldredge 18).

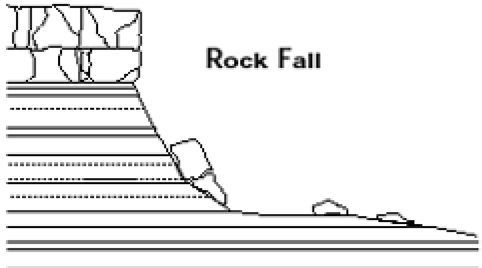
Three Common Types of Landslides in Utah



Debris flows consist of sediment-water mixtures that flow down a streambed or hillside, commonly depositing sediment at canyon mouths in fan like deposits know as alluvial fans.



Slides are down slope movements of soil or rock on slopes.



Rock falls consist of rock(s) falling from a cliff or cut slope and are very common in the canyon country of southern Utah.

Conditions That Make Slopes More Susceptible to Landslides

- Discontinuities: faults, joints, bedding surfaces.
- Massive Materials over soft materials.
- Orientations of dip slope: bedding plans that dip out of slope.
- Loose structure and roundness.
- Adding weight to the head of a slide area: rain, snow, landslides, mine waste piles, buildings, leaks from pipes, sewers, and canals, construction materials fill materials.
- Ground shaking: earthquakes or vibrations.
- Increase in lateral spread caused by mechanical weathering.
- Removal of lateral support.
- Human activities: cut and fill practices, quarries, mine pits, road cuts, lowering of reservoirs.
- Removing underlying support: under cutting of banks in a river.
- Increase in pore water pressure: snow melt, rain, and irrigation.
- Loss of cohesion.

Wildfire

A wildfire is an uncontrolled fire spreading through vegetative fuel often exposing or consuming structures. Wildfires often begin unnoticed and spread quickly and are usually sighted by dense smoke. Wildfires are placed into two classifications Wildland and Urban-Wildland Interface. Wildland fires are those occurring in an area where development is essentially nonexistent, except for roads, railroads, or power lines. Urban-Wildland Interface fire is a wildfire in a geographical area where structures and other human development meet or intermingle with wildland or vegetative fuels.

When discussing wildfires it is important to remember that fires are part of a natural process and are needed to maintain a healthy ecosystem. Three basic elements are needed for a fire to occur (1) a heat source (2) oxygen and (3) fuel. Major ignition sources for wildfire are lightning and human causes such as arson, recreational activities, burning debris, and carelessness with fireworks. On average, 65 percent of all wild fires started in Utah can be attributed to human activities. Once a wildfire has started, vegetation, topography and weather are all conditions having an affect wildfire behavior.

Severe Weather

For the purpose of this mitigation plan the term severe weather is used to represent downbursts, lightening, heavy snowstorms, blizzards, avalanches, hail, and tornados.

Downbursts

A downburst is a severe localized wind, blasting from a thunderstorm. Depending on the size and location of these events, the destruction to property may be devastating. Downbursts fall into two categories by size. Microbursts cover and area less than 2.5 miles in diameter. Macrobursts cover an area with a diameter larger then 2.5 miles.

Lightening

During the development of a thunderstorm, the rapidly rising air within the cloud, combined with the movement of the precipitation within the cloud, causes electrical charges to build. Generally, positive charges build up near the top of the cloud, while negative charges build up near the bottom. Normally, the earth's surface has a slight negative charge. However, as the negative charges build up near the base of the cloud, the ground beneath the cloud and the area surrounding the cloud becomes positively charged. As the cloud moves, these induced positive charges on the ground follow the cloud like a shadow. Lightening is a giant spark of electricity that occurs between the positive and negative charges within the atmosphere or between the atmosphere and the ground. In the initial stages of development, air acts as an insulator between the positive and negative charges. When the potential between the positive and negative charges becomes to great, there is a discharge of electricity that we know as lightning.

Heavy Snowstorms

A severe winter storm deposits four or more inches of snow during a 12-hour period or six inches of snow during a 24-hour period. According to the official definition given by the U.S. Weather Service, the winds must exceed 35 miles per hour and the temperature must drop to 20° F or lower. All winter storms make driving extremely dangerous.

Blizzards

A blizzard is a snowstorm with sustained winds of 40 miles per hour (mph) or more or gusting winds up to at least 50 mph with heavy falling or blowing snow, persisting for one hour or more, temperatures of ten degrees Fahrenheit or colder and potentially life-threatening travel conditions. The definition includes the conditions under which dry snow, which has previously fallen, is whipped into the air and creates a diminution of visual range.

Hail Storms

Hailstones are large pieces of ice that fall from powerful thunderstorms. Hail forms when strong updrafts within, the convection cell of a cumulonimbus cloud carries water droplets upward causing them to freeze. Once the droplet freezes, it collides with other liquid droplets that freeze on contact. These rise and fall cycles continue until the hailstone becomes too heavy and falls from the cloud.

Drought

Drought is a normal recurrent feature of climate, although many, in Utah, erroneously consider it a rare and random event. It occurs in virtually all-climatic zones, while its characteristics vary significantly from one region to another. Droughts, simple put, are cumulative hazards, which result from long periods of below normal precipitation. Drought is a temporary aberration and differs from aridity since the latter is restricted to low rainfall regions and is a permanent feature of climate.

The State of Utah uses the Palmer Drought Severity Index or (PDSI) to quantify the existence of a drought. Using the PDSI, drought is expressed as a negative number. Much of the basis, used by the State, to determine drought years, or drought periods, comes from the PDSI. In addition, the PDSI is used by the State Climatologist, the National Geophysical Data Center of NOAA, and the National Drought Mitigation Center.

For the most part droughts no longer affect the availability of drinking water, thus no longer place peoples lives at risk, the same can not be said for a persons livelihood. Numerous water projects throughout the state have placed enough water in storage to insure drinking water. Prolonged droughts have a significant affect on agricultural and agribusinesses, within the state dependent on irrigation water. Droughts also stress wildlife, and heighten the risk of wildfire.

Dam Failure

Dam failures result from the failure of a man made water impoundment structure, which often results in catastrophic down grade flooding. Dam failures are caused by one or a combination of the following: “breach from flooding or overtopping, ground shaking from earthquakes, settlement from liquefaction, slope failure, internal erosion from piping, failure of foundations and abutments, outlet leaks or failures, vegetation and rodents, poor construction, lack of maintenance and repair, misuse, improper operation, terrorism, or a combination of any of these” (Eldredge 46). The Utah State Engineer has been charged with regulating non-federal dams in the State dams since 1919. “In the late 1970's Utah started its own Dam Safety Section within the State of Utah Engineers Office to administer all non-federal dams in response to the Federal Dam Safety Act (PL-92-367)” (Eldredge 46).

The State Dam Safety Section has developed a hazard rating system for all non-federal dams in Utah. Downstream uses, the size, height, volume, and incremental risk/damage assessments or dams are all variables used to assign dam hazard ratings in Dam Safety’s classification system. Using the hazard ratings systems developed by the Dam Safety Section, dams are placed into one of three classifications high, moderate, and low. Dams receiving a low rating would have insignificant property loss do to dam failure. Moderate hazard dams would cause significant property loss in the event of a breach. High hazard dams would cause a possible loss of life in the event of a rupture. The frequency of dam inspection is designated based on hazard rating with the Division of Water Rights inspecting high-hazard dams annually, moderate hazard dams biannually, and low-hazard dams every five years.

HAZARD ANALYSIS PROCESS

Geographic Information Systems (GIS) was used as the basic analysis tool to complete the hazard analysis for this report. For most hazards a comparison was made between mapped sources of hazard data and mapped layers that delineate where existing development is located. Data sources of existing development was obtained from a 1996 study conducted by the State of Utah Division of Water Resources that mapped water related land uses. Although the type of development was not determined, this study did identify geographically those areas where some sort of development has occurred. 1992 digital ortho aerial photographs as well as 2000 Census Block Group data was also used to determine the areas at risk and the magnitude of the risk.

One of the goals of this study is to estimate the number of homes, number of people, and dollar value of residential structures within any given hazard area. To this end, census data and natural hazard maps are the basic information used in the analysis. All the analysis takes place within the spatial context of a GIS. With the information available in spatial form, it is a simple task to overlay the natural hazards with census data to extract the desired information. For instance, to find the census blocks that in some manner affected by a hazard area. Once the census blocks have been identified, it becomes a matter of adding up the desired information from the census data. In this case we tally up the number of people and houses in each block. It is also possible to determine total home values of each block by multiplying the average block-group house value with total number of homes in the block. Hence we estimate the dollar value of homes within a hazard area at a block level.

It was realized early on, however, that even at a block level, census data can still be too spatially disaggregate for suitable results. In other words, census blocks do not show exactly where the variables that are being measured (i.e. houses, people, and house value) really exist. For example, if a small portion of a census block is in a hazard area it causes the entire block to be counted. In effect, all the homes in a census block are considered within the hazard area instead of the one or two that may truly be affected by the hazard. If this method had been used, then the results of the analysis would have overestimated the amount of each variable in a hazard area. Due to the possibility of significant error additional steps have been added for the analysis.

The first change to the original method is to add an additional data set that shows developed areas throughout the study area. Called the Water Related Land Use (WRLU), this land use classification allows the census information to be more precisely placed on the landscape. For the analysis, the WRLU was merged with census block boundaries. It is then assumed each variable given in the Census data for a given block can be place on the land considered developed in that block. Unfortunately, this method still has its shortcomings. While it more precisely locates the where homes are, it still doesn't fix the problem of a hazard only partially affecting a census block.

To deal with this situation, the census data for a given block is converted into a density value. Here is a hypothetical example, if the developed area of a given census block, say 10,000 meters^2, contains 150 people, then resulting population density is .015 people/meter^2. This same process can be used to calculate the two other variables, housing density (house/meter^2) and a housing value density (dollar/meter^2). Having calculated the three densities it is only a matter of determining the amount of space that a hazard occupies in the developed areas of each census block. Once that amount is known, it is multiplied by the density of the variable. Say, for example, that a hazard covers 2000 meters^2 of developed area in the hypothetical block above. The total people affected by the hazard would be 2000 meter^2 multiplied by .015people/meter^2 or 30 people. This process is performed for each block and the results are added together. It is in this manner that the total effects of a potential hazard are calculated for the study area.

A few assumptions had to be made in order to execute this model and produce results given the data available. The model is based on the assumption that both population and housing unit density is uniformly distributed across the areas identified as developed in the WRLU database (correlated to the census block). The housing unit value assigned to the Census Block was based on the figure provided in the Census Block Group (this variable is not available at the block level). The Census 2000 “Average Owner Occupied Home Value” category was used. This model assumes total loss and does not separate residential building and land values nor does it account for the potential for partial losses (for example flooding of basements).

The potential loss estimates for commercial development (excluding home-occupation businesses) were determined by intersecting the various hazard data layers with a commercial\industrial business location GIS data layer. In this way, we were able to derive the number of businesses that were located in each hazard and their total estimated 2002 sales revenue.

Working with the various county tax assessors’ offices, an attempt was made to look up the tax assessed value of all the businesses located in hazard zones. It was soon determined that the data could not be automatically extracted from the assessor’s data bases. Each business would have to be looked up and pulled individually. With over 1000 businesses located in one or more hazard zones in the three counties, this proved too difficult.

As an alternative, the potential loss value of the commercial/industrial structures were determined by calculating an average 2002 value for each county and multiplying this figure by the number of businesses. The average value was calculated by dividing the total assessed value (land & buildings) obtained from a 2002 property tax report from the Utah State Tax Commission by the number of assessed businesses in each of the counties (obtained by each of the county’s Assessors). Based on these calculations, the average business land & building value for Box Elder County was $343,872, Cache County $505,637 and Rich County $147,100. Unfortunately, this method will only provide a very rough approximation of commercial/industrial property at risk.

In terms of hazard mapping presentation in this document, portions of western Box Elder County and Eastern Cache County were excluded. These areas were not excluded from hazard identification and analysis. The decision to exclude these areas from the presentation mapping was designed to enhance the readability and usefulness of the mapping. Box Elder County has one of the largest geographic boundaries in the nation, yet only about 444 persons (1% of the county's population) reside in the western portions; an area about five times the size of the more populated eastern portion of the county. Small unincorporated ranching communities such as Grouse Creek, Yost and Park Valley are located in Western Box Elder County. All incorporated cities were included in the mapping. Eastern Cache County was excluded from the mapping because it's mostly U.S. Forest Service land and virtually uninhabited (at least year round). Some second home cabin development is located in eastern Cache.

Areas not mapped in the presentation of the data were treated exactly the same as mapped portions in terms of hazard identification and analysis. Hazards issues for these portions excluded from mapping will be covered in the narrative portion of the document to the extent needed.

Effort to analyze hazards related to potential future development areas was also addressed where applicable. This proved to be a very difficult exercise and at best can identify general development trends and where potential conflicts may occur. No viable source of data exists to facilitate this sort of analysis. Zoning data does not necessarily indicate an area will be developed with a particular land use. Other development constraints such as availability of water/sewer or restrictions imposed by other general ordinances or regulations make the predictability of zoning difficult if not impossible. Nonetheless, an attempt was made to describe general growth trends as they related to particular hazards.